Dealing with societal challenges of a circular economy in engineering education

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Abstract

On December 2nd, 2015 the European Commission published a new Circular Economy Package to stimulate Europe's transition towards a circular economy, aimed at boosting global competitiveness, fostering sustainable economic growth, decreasing carbon emissions, and generating 580,000 new jobs. The engineers educated today will be key role players in this ambitious plan. An important focus in circular economy education lies in aspects of resource efficiency, using less raw materials and energy, and innovative processes and products. Whereas this is a certainly challenging to stimulate the creativity, innovation, and entrepreneurial spirit of engineering students, social aspects of the circular economy perspective cannot be neglected and definitely deserve more attention.

Both producers and consumers play a role in the transition towards a circular economy. Although general public awareness about the circular economy will likely increase in the coming years, usability, acceptability, and user incentives are essential to design successful circular systems. It is here that engineers can play an important role, in engineering and designing their products so that they are accepted by the consumers. Besides the environmental impact of materials and products over their entire life cycle, social impacts (such as the social well-being of different actors and stakeholders in the value chain of a product), are receiving more and more attention. Social wellbeing is not only enhanced through resource efficiency improvements, but also by issues of societal concern, for example: job creation, labor conditions, transparent communication about a product (over its entire life cycle), etc.

In the present paper, we discuss some examples of how the societal impact of the circular economy concept can be addressed in courses and curricula in engineering education and beyond. Attention is paid to the role of life cycling thinking in adopting the circular economy concept, thus addressing environmental, economic, and social aspects. Examples also show the importance of taking into account consumer behaviour to analyse problems associated with human use of goods and services, within a circular economy framework Finally, we illustrate some interesting examples on truly interdisciplinary (student) projects.

1 Introduction

The recently published Circular Economy Package (COM, 2015) aims to stimulate Europe's transition towards a circular economy, and engineers educated today will be key role players in this ambitious plan. An important focus in circular economy education lies in aspects of resource efficiency, using less raw materials and energy, and asking for innovative processes and products. Whereas this is a certainly challenging to stimulate the creativity, innovation, and entrepreneurial spirit of engineering students, social aspects of the circular economy perspective cannot be neglected and definitely deserve more attention. Engineers are trained to develop creative applications of science, with the aim to improve peoples' lives. Therefore, engineering education should also focus on raising the awareness for societal issues. Societal problems often determine what questions engineers tackle. Besides being experts in technology, they should also be trained to understand people, and to interact with people in such a way that they act as a mediator between people and technology. The technologies that are the products of engineering, as well as newly developed business models emerging from these innovations, influence society, not only by having an environmental impact, but they also affect human culture. The circular economy is about re-designing products to tackle planned obsolescence; moving from product to service thinking (the leasing or sharing economy); and re-designing supply chains, business models and organizations (ESCAP, 2014).

In the present paper we will first discus some ways to address social/societal issues of circular economy, within the framework of already existing course contents (i.e., Life Cycle Analysis (LCA) and sustainable design) of engineering curricula. We will also illustrate the importance of taking into account consumer behavior to analyze problems associated with human use of goods and services, within a circular economy framework Finally, we will elaborate on the role of interdisciplinarity and project-based learning, illustrated with some interesting examples on truly interdisciplinary (student) projects.

2 Addressing societal impact of circular economy

Methodologies, techniques, and tools have been developed for the sustainability assessment of product and process assessment, often to support policies and strategies for the social, economic, or the environmental dimension of sustainable development. Nowadays, life cycle thinking and LCA is being included in many engineering curricula focussing on process and product design. Although LCA classes are most often offered in engineering programs, it is increasingly taught in other fields, including chemistry, design, and architecture. The Environmental Product Declarations (EPD), a verified and registered document that communicates transparent and comparable information about the life-cycle environmental impact of a product, is an example of the practical application of LCA in the construction sector. The LCA methodology used for EPDs encourages using recycled material and for designing products that may be reused or recycled, thus steering towards products that are part of a circular economy. Nevertheless, LCA focusses on environmental aspects, not allowing a full sustainability assessment. In recent years, several efforts have been pursued to cover, in a more coherent and integrated way, all pillars of sustainable development, striving for a more holistic sustainability evaluation of goods and services.

2.1 Social life cycle assessment to complement environmental LCA and LCC

Environmental impacts are much more frequently standardized and quantified than social and socio-economic ones (Dreyer *et al*., 2006). Because LCA focusses on assessing environmental impacts of goods and services, it is not uncommon that the interpretation of the results, and the recommendation drawn from the results, are in conflict with other interests in product such as economic or social considerations (e.g. labor conditions, intergenerational equity, etc.). The full sustainability assessment of goods and services can be performed through life cycle sustainability assessment (LCSA), combining three techniques: environmental LCA (E-LCA), life cycle costing (LCC), and social LCA (S-LCA). (Schau *et al*., 2012). Social LCA's can add an extra dimension to this environmental impact analysis. Because the whole life cycle of a product is taken into account, S-LCA results in a more holistic view on the social impact of product compared to other methods to evaluate social aspects (Jørgensen, 2013).

Despite the fact that methodology of S-LCA is still under development (Sala *et al.*, 2015), this framework could already be used in education to address societal issues of goods and services that are being developed within a circular economy concept. Because the basic steps of an LCA can also be adopted in S-LCA, S-LCA could find a place in engineering curricula in courses where ”traditional” LCA is addressed, even without going in-depth on all social aspects included in S-LCAs.

2.2 Sustainable design in higher education

Ecodesign is the concept of taking environmental issues into consideration when designing and developing new products, or when updating existing products. Ecodesign focuses primarily on the environmental and economic dimensions of sustainable development, but does include aspects of the social dimension. Environmental and social impacts and management of resources from cradle to cradle are all important elements of the engineering context of sustainability (Boyle, 2004). Whereas ecodesign is considered a sub-discipline of sustainable design, ecodesign often also includes aspects of corporate social responsibility (i.e., healthy and safe working conditions, etc.), making the distinction between both terms not always very clear.

The Flanders’ Materials Program combines ambitious long-term vision development, experimental pilot projects, policy-relevant research, and concrete priority actions in order to accelerate the transition to a circular economy. Sustainable design is one of the action domains of this program. Based on a screening of higher education for its potential impact on the design, service, and product launch, a list of opportunities and limitations concerning the integration of ecodesign in higher education in Flanders was made (Verhulst and Van Doorselaer, 2015). This knowledge was used to develop a tailored training package the, Ecodesign in Higher Education (EHE)-Kit, primarily developed for engineering courses (Verhulst and Van Doorselaer, 2015). It has been developed in and for the Flemish region (Belgium) but is now also available in English and can be applied in other countries and other disciplines, such as in management education. Since 2013, the Flemish design colleges have signed an agreement in which they commit themselves to incorporate sustainable design into their training.

3 Consumer acceptance and awareness

Whereas the benefits of the circular economy are more and more recognized, several barriers to the transition have been identified (European Commission, 2014), including limited consumer and business acceptance of potentially more efficient service-oriented business models, (e.g. leasing rather than owning), and shortfalls in consumer awareness.

Besides training engineers in basic and applied sciences, sustainable materials management, recycling methods, and life cycle assessment (LCA), they should also be trained to become key-persons in any industry facing the implementation of the circular economy concept. Making the transition to a circular economy asks for new skills across different disciplines. Although circular economy is strongly linked to the way materials are used and how products are designed, there are also important implications for changes in consumer behavior and business models.

3.1 Risk perception towards products emerging from circular economy.

Several interesting examples have been described in literature, showing that the acceptance of circular economy products and services by the general public should not be taken for granted. Refurbishment is the process of collecting a used product, assessing its condition, and replacing certain parts in order to resell the product to new consumers. From a circular economy perspective, refurbishment is identified as a promising design strategy to reduce the environmental impact of consumption goods, because it reduces waste and the use of scarce resources. However, refurbishment will only have a positive effect on society if it is widely applied and accepted in consumer goods. Van Weelden *et al*. (2016) explored consumer perceptions of refurbished mobile phones. The results suggest there are some important barriers to consumers choosing refurbished phones. The study showed that the people misunderstood what refurbishment means, associating refurbishment to second-hand, and believing that phones may be damaged and not fully functioning. Consumers felt purchasing a refurbished phone would not provide the same enjoyment as owning a new phone.

Another study on the use of dredged sediments as a resource for brick production (Cappuyns *et al*., 2015) showed that consumers in Flanders are rather suspicious with respect to bricks produced from dredged sediments and their risk perception is mainly determined by the possibility of a bad bargain (brick of inferior quality) and the connotation with chemical contamination. While the risk perceived by a consumer can be based on the physical risk of using a product, there is typically a discrepancy between consumer and scientific risk evaluations. Besides personal characteristics, product characteristics also play a role in risk perception. In general, a higher risk is attributed to more complex products compared to ordinary ones with a lower (monetary) value (Mitchell, 1999). Sensitization and information of customers seems to be of primary importance to make this kind of products successful.

3.2 Acceptance of circular business models

Engineering education has evolved over the last decades from a purely technical education to an education including entrepreneurial skills in order to understand the context of market and business pressures. This entrepreneurship-focused education gives them solid experience in product design and development, prototyping, technology trends, and market analysis (Nelson and Byers 2010). Nowadays, engineering students are also trained to develop business models, commercialize new and existing products, and to transfer technology.

Based on a literature review, Van Eick (2015) concluded that, "*Circular Economy demands a system change with parallel actions along the value chain rather than a purely sector and/or product focused approach. This also requires institutional changes, cultural changes, technological innovation and knowledge development & exchange just as closer cooperation and transparency between all actors (governments, businesses, inhabitants and the science & education community).*"

Despite the fact that circular business models provide huge opportunities for companies, customers, and the environment, their benefits alone will not translate into widespread acceptance of the idea of circular economy business models. Besides rational motives, non-rational motives of consumer behavior have to be taken into account, including the habits and routines of individuals (Planing, 2016).

4 The circular economy as a subject of interdisciplinary student projects

Multiple aspects of circular economy can also be addressed in student projects in which students from different background work together. During interdisciplinary projects, the students become aware of their specific disciplinary contribution, they learn to communicate without using technical jargon, and discover their critical role towards persuasive information (Mulder, 2006). The success of a project does not only depend on individual performances, the capacity of the group to work as a team, is also a key factor of success.

We describe two interesting examples of interdisciplinary student projects, one on the international level, the other on the national (university) level, in which different key elements for a circular economy (ecodesign and sustainable resource management) are addressed, taking into account technical, environmental, economic, and social aspects.

4.1 European Project Semester (EPS)

A European Project Semester (EPS) falls within the Erasmus student exchange program and provides international multidisciplinary project (e.g. in the field of industrial design) training in teams. EPS is a mixture of "project related courses" and project organized/problem based learning. Students work in international and preferably interdisciplinary teams of 3–6 students on their projects (e.g. Malheiro et al., 2015). Besides the project itself, credits are reserved for general subjects such as culture, language, team building, project management, and theory in support of the project. Ecodesign can be integrated within an EPS programme, (Verhulst *et al*. 2015) with projects that often provide an interesting starting point for a product-service combination. The *Univeristat Politéchnica de Catalunya* proposes an International Design Project Semester (IDPS), a one-semester course designed to train final-year industrial design engineering students to work in international teams.

4.2 Interdisciplinary assessment Project (IAP)

The Interdisciplinary Assessment Project (IAP) is a course offered at KU Leuven (Belgium) , for students in Environmental Health and Safety management, Commercial Engineering, and Applied Engineering Sciences. This course gives students the opportunity to cooperate in interdisciplinary teams to resolve real-life cases of business problems. In these cases, economic, technical, and sustainability issues are brought together and resolved. The 2014 edition of the IAP focused on sustainable resource use and included projects of companies in the automobile, electronics, manufacturing, materials, and energy sectors. The winning project dealt with tools, technologies, and products for enhanced landfill mining (ELFM), an innovative new business concept to valorize materials and energy from abandoned landfill sites.

In this kind of projects, plenty of opportunities can be found to address the wider societal impact of circular economy, by including, for example, issues such as communication with stakeholders, external costs and benefits, etc. From the perspective of people living in the neighborhood of ELFM facilities, they are often seen as a potential threat to health, safety or prosperity. However, they often represent opportunities for business and society. Private investors typically do not take into account external benefits or costs to society, as these are not fully borne by the private investor (Van Passel *et al.*, 2013). Examples of beneficial effects of ELFM include lower environmental pollution, restoration of nature and biodiversity, and reduced import dependency. An investigation of local community participation in an enhanced landfill mining project (Sips et *al.*, 2013), showed that setting up a multi-actor platform, organizing a group of involved locals, and involving local people as bridge figures (combining formal and informal communication channels), etc. can tackle these problems.

5 Conclusion

The European Academies' Science Advisory Council (EASAC, 2015) reviewed the benefits foreseen for a circular economy and potential risks for the transition phase. Among others, lack of circular economy programs at all levels of education, and the lack of information/awareness (on alternative options and economic benefits) are considered important barriers in a transitions towards a circular economy.

Besides the environmental and economic benefits that are expected from a transition towards a circular economy, many societal challenges deserve the necessary attention. Whereas the focus in engineering education is still on technological and environmental aspects, several opportunities to address societal aspects of goods and services from a circular economy exit. The circular economy concept can be addressed in engineering education, even without specific circular economy programs or courses. S-LCA can be used to include social aspects of goods and services, within a life cycle perspective to complement environmental LCA and LCC. Social aspects inherently linked with circular economy goods and services are also addressed in courses on sustainable design, and consumer behavior, and their importance for engineering education should not be neglected.

Finally, interdisciplinary projects offer many opportunities, not only to acquire knowledge on the circular economy concept and its practical implementation, but also increase students' awareness of societal impact of the goods and services they develop. Moreover student develop soft skills (e.g. communication, stakeholder engagement, etc.) that are essential to make circular economy-based goods and services acceptable for the general public.

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